
Appendix A. Methods for Measuring Particles

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Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air

Contaminant	Method Type	Type of Measurement <i>Continuous</i> <i>Intermittent</i> <i>Integrated</i>	Type of Sampler <i>Passive</i> <i>Active</i>	Collection Method <i>filter</i> <i>sorbent</i> <i>denuder</i>	Sampling Device	Analytical Method	Range of Quantification (or detection)
Carbon monoxide (CO)	Gas Filter Correlation Ambient CO Analyzer	Continuous	Active	Air is drawn into the monitoring system (instruments commercialized)	Monitoring system (1 L/min)	Sampled CO is measured by IR (infrared radiation at 4.6 μm)	0.1 - 100 ppm
	Personal Air Control (Pac III)	Continuous/Integrated	Active	—	User installable »plug and play« electrochemical Dräger Sensors	—	
	Tedlar bags, GC, reduction gas detector	Integrated	Active	Air is collected into Tedlar bags using pumps	Tedlar bags, pumps	Air samples are separated and CO is detected with a reduction gas detector (HgO to Hg vapor by CO)	0.30 ppm -
	Activated charcoal tube, color change	Integrated	Active	Air is pumped thru activated charcoal tubes	Tubes	Color change when CO is present	
	Solid adsorbent, GC/FID	Integrated	Passive	Air is diffused through diffusion tube onto Zn-Y-zeolite in the glass tube	Diffusion tube, glass tube (Zn-Y zeolite), stainless steel screen, rubber septum	CO is thermally desorbed and then converted to methane, which is analyzed by GC/FID	30 - 1,600 ppm-h
	Diffusion type dosimeter	Integrated	Passive	Diffusion of air into the dosimeter	Purified silica gel impregnated with a detecting chemical (palladium salt) in passive dosimeter	Length of stain (direct reading): color change from very pale yellow (almost white) to gray	1 mg/m^3 (0.87 ppm) -
Nitrogen dioxide (NO ₂)	Personal Air Control (Pac III)	Continuous/Integrated	Active	—	User installable »plug and play« electrochemical Dräger Sensors	—	
	Sodium arsenite, colorimetry	Integrated	Active	Air passes through a solution of basic (NaOH) sodium arsenite	Standard impingers containing basic sodium arsenite solution	Add H ₂ O ₂ followed by sulfanilamide and NEDA --> absorbance at 540 nm	0.005 - 0.15 ppm
	Sodium arsenite, colorimetry, continuous	Continuous	Active	Air passes through a solution of basic (NaOH) sodium arsenite	An orifice bubbler	Add H ₂ O ₂ followed by sulfanilamide and NEDA --> absorbance at 540 nm	0.005 - 0.15 ppm

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	Chemiluminescence after conversion of NO ₂ to NO	Continuous	Active	Monitoring system (instruments commercialized)	Monitoring system	NO ₂ to NO, which is measured by chemiluminescence	0.25 (0.005 ppm - MDL) - 25 ppm
	UV differential optical absorption spectrometry (DOAS)	Continuous	—	Light (laser) passes through the air (3 to 1000 m)	Direct reading	Light intensity is proportional to the concentration of NO ₂	0.004 - 0.5 ppm
	TGS-ANSA Method	Integrated	Active	Ambient air is bubbled with an orifice bubbler	An orifice bubbler, a solution of TEA, guaiacol, and sodium metabisulfite (TGS)	NO ₂ is reduced to NO, which then reacted with sulfanilamide and 8-amino-1-naphthalene-sulfonic acid ammonium salt (ANSA)	0.008 - 0.15 ppm
	Triethanolamine (TEA)-impregnated molecular sieve, IC	Integrated	Active	Air is drawn into a sampling tube containing TEA-impregnated molecular sieve	Sampling tube, a calibrated pump (0.2 L/min)	The sample is desorbed using 1.5% TEA solution. NO ₂ ⁺ is analyzed by IC	0.19 ppm (3-L air) -
	Palmer-type diffusion tube, spectrophotometry	Integrated	Passive	NO ₂ is absorbed into three screens coated with triethanolamine (TEA) --> TEA-NO ₂ complex	Palmer diffusion tube (acrylic tube), 3 screens, fixed cap, flanged (removable) cap	Color development by a color reagent (sulfanilamide + NEDA) --> absorbance at 540 nm	0.01 µg NO ₂ per sample (0.150 ppm-h) -
	Ferm badge, FIA	Integrated	Passive	A mixture of iodide, arsenite and ethylene glycol	Badge type - a filter impregnated with a mixture of three chemicals, a wind shielded inlet	Spectrophotometry (flow injection analysis, FIA)	0.05 - 200 ppm
	Ogawa badge, TEA, IC	Integrated	Passive	NO ₂ forms a complex with TEA (glass fiber filter)	A glass fiber filter impregnated with TEA, a protective cage	IC (suppressed)	N/A
	CSPSS badge, CHEMIX TM , spectrophotometry or CFA	Integrated	Passive	NO ₂ forms a complex with TEA (CHEMIX TM)	Teflon film (diffusion barrier), CHEMIX TM (collection medium), two polyester screens, sampler body)	Spectrophotometry, CFA or (IC)	0.0001 - 0.050 ppm (1 month)

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Tyoe	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	Triethanolamine (TEA), IC	Integrated	Passive	Diffusion onto a TEA-coated filter	A badge type (25 mm * 10 mm), Whatman 1 Chr filter paper (or two SS screens impregnated with TEA)	NO ₂ is extracted with deionized water and the extract is analyzed by IC	0.5 µg/m ³ (1 month), 15 µg/m ³ (24 hr) -
	Yanagisawa-type sampler, TEA, Spectrophotometry	Integrated	Passive	Diffusion onto a TEA-coated filter	Polyethylene bag (rain shelter), absorbent filter, pre-filter	Extracts (with DI water) are analyzed by measuring absorbance at 545 nm (Saltman reagent)	N/A
Ozone (O ₃)	Chemiluminescence O ₃ analyzer, ethylene	Continuous	Active	Air is drawn into a reaction cell	A pump, filter, a reaction cell	Measure an analyte by mixing it with ethylene with which it reacts to form light	0.002 - 0.5 ppm
	Chemiluminescence O ₃ analyzer, ethylene, Rhodamine B organic dye	Continuous	Active	Air is drawn into a reaction cell	A pump, filter, a reaction cell	Measure an analyte by mixing it with ethylene with which it reacts to form light	0.002 - 0.5 ppm
	UV Photometry	Continuous	Active	Optical absorption cell (instruments commercialized)	Air is continuously drawn through an optical absorption cell (1.5 to 2 L/min)	Drawn air is irradiated by UV (254 nm) and absorbance is measured	0.002 - 1 ppm
	UV differential optical absorption spectrometry (DOAS)	Continuous	—	Light (laser) passes through the air (3 to 1000 m)	Direct reading	Light intensity is proportional to the concentration of ozone	0.0015 - 0.5 ppm
	Personal sampler using a diffusion denuder	Integrated	Active	Air is drawn into a diffusion denuder (65 mL/min)	Hollow tube denuder (HTH, 1.4 cm id * 10 cm L)) coated with nitrite		0.045 ppm -
	Active, Impregnated glass fiber filter, IC-UV	Integrated	Active	Two nitrite-impregnated glass fiber filters (NIGFFs)	A two-piece polystyrene cassette containing two NIGFFs.	NO ₃ ⁻ extracted with DI water and the extracts analyzed by IC-UV (Conduc.)	0.03 ppm (90-L air) -
	Bubbler, Vis spectrophotometry	Integrated	Active	0.5% 1,2-Di(4-pyridyl)ethylene (DPE) in glacial acetic acid	All-glass fritted bubbler, absorber, an air pump	Color-developing reagent (0.2% aq. 3-methyl-2-benzothiazolinone hydrazone HCl, 3-MBTH), 442 nm	N/A

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Tyoe	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	Filter in a plastic tube, Vis spectrophotometry	Integrated	Passive	Glass fiber filter impregnated with 1,2-Di(4-pyridyl)ethylene (DPE), PVC tube	A piece of glass fiber filter contained in a PVC tube	Color-developing reagent (0.2% aq. 3-methyl-2-benzothiazolinone hydrazone HCl, 3-MBTH), 442 nm	0.003 mg/m ³ (1 wk) -
	UV spectrophotometry	Integrated	Passive	Gel Blot paper loaded with Indigo	Can Oxy Plate™	Isatin is extracted with ethanol and absorbance is determined at 408 nm.	N/A
	Reflectance spectroscopy (color analyzer)	Integrated	Passive	Paper disc coated with indigo carmine + PTFE filter (diffusion barrier)	25 mm diameter polycarbonate dual filter	Color change before and after sampling measured by reflectance spectroscopy (color analyzer)	0.03 ppm (24 hr) or 0.001 ppm (1 month) -
	Diffusion, IC-Conductivity	Integrated	Passive	Glass fiber filters coated with NaNO ₂ (c-HNO ₃ --> chromic acid sulfuric acid --> c-HCl --> NaOH)	Ogawa & Co., USA passive sampler	A reaction product, nitrate (NO ₃ ⁻), is extracted with DI water and the extracts analyzed by IC-Cond.	0.017 ppm (12 hr) or 0.008 ppm (24 hr) -
	Diffusion, IC-UV	Integrated	Passive	Filter coated with sodium nitrite, potassium carbonate, and glycerol	Teflon barrel-shaped body containing two coated fiberglass filters + a Teflon diffusion barrier (Ogawa & Co.)	A reaction product, nitrate (NO ₃ ⁻), is extracted with DI water and the extracts analyzed by IC-UV	~ 0.017 - (12 hours)
	Diffusion, IC-UV	Integrated	Passive	Filter coated with sodium nitrite	Teflon film as a diffusion barrier + sampling media (filter)	A reaction product, nitrate (NO ₃ ⁻), is extracted with DI water and the extracts analyzed by IC-UV	0.003 - 1 ppm for 1-day exposure; 0.0001 - 0.14 ppm for 1 month exp.
	I ₂ /Nylon-6 charge-transfer complex, coulometry	Integrated	Passive	Collector (carbon disk coated with nylon-6, KI, KH ₂ PO ₄ , and CH ₃ COOK), KMnO ₄ glass filter, etc.	Collector, Teflon membrane, Teflon spacer, Teflon mesh, KMnO ₄ glass filter, Teflon membrane, and Teflon mesh in series	Coulometry (discharge measurement system)	0.4 ppm-h - 1.4 ppm-h
	Rubber cracking	Integrated	Passive	Vulcanized rubber is exposed to air	Vulcanized rubber (mix with sulfur and heat above 100°C --> highly elastic)	Image analysis --> frequency of cracks of a given length is proportional to ozone conc.	~0.060 ppm (24 hr)

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Tyoe	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	Personal Air Control (Pac III)	Continuous/Integrated	Active	—	User installable »plug and play« electrochemical Dräger Sensors	—	
Sulfur dioxide (SO ₂)	Pararosaniline method, Spectrophotometry	Integrated	Active	Air is bubbled through a solution of 0.04 M potassium tetrachloromercurate	Glass midget impinger for short-term (0.5 - 1.0 L/min)	Spectrophotometry (548 nm) - pararosaniline reagent	25 µg/m ³ (0.01 ppm) - 1,130 µg/m ³ (0.43 ppm) for short-term sampling
					Polypropylene (PP) tube for long-term (0.18 - 0.22 L/min)		13 µg/m ³ (0.005 ppm) - 590 µg/m ³ (0.23 ppm) for long-term sampling
	UV Fluorescent SO ₂ analyzer	Continuous	Active	Air is drawn onto 5 to 10 µm PTFE filter (instruments commercialized)	2.5 L/min, filter assembly	Automated, fluorescent detector	0.0004 - 1.0 ppm
	UV differential optical absorption spectrometry (DOAS)	Continuous	—	Long path measurements (3 to 1000 m)	—	Light intensity is proportional to the concentration of NO ₂	0 - 0.5 ppm or 0 to 1.0 ppm
	Gas wash bottle method (H ₂ O ₂ , IC)	Integrated	Active	Air is drawn through a gas wash bottle containing an acidified H ₂ O ₂ solution	A pump (1.1 L/min), an inverted funnel, polypropylene tubing, a cellulose filter, a gas wash bottle	SO ₂ is converted to H ₂ SO ₄ by H ₂ O ₂ , which is measured by suppressed IC	0.8 µg/m ³ -
	Filter pack method (NaOH, IC)	Integrated	Active	Air is drawn through a NaOH-impregnated filter	A pump (14 L/min), filter pack	SO ₄ ²⁻ is extracted with DI water and the extract analyzed by IC	0.08 µg/m ³ -
	Sulfation measurement with lead dioxide	Integrated	Passive	Air is diffused onto a glass fiber filter coated with lead dioxide (sulfation plate)	Platic petri dish (badge typed), a glass fiber filter coated with lead dioxide	Turbidometric barium sulfate procedure - turbidity is measured by spectrophotometry	N/A
	Permeation, spectrophotometry	Integrated	Passive	Diffusion onto a permeation device (Na ₂ HgCl ₄)	Silicone membrane (Na ₂ HgCl ₄ soln), 41 mm OD tube, rubber stopper, and 1 mm OD capillary	Add pararosaniline and formaldehyde solutions --> absorbance at 575 nm (Wet-Gaeke procedure)	N/A
	Permeation, ion-exchange chromatography	Integrated	Passive	Diffusion onto a permeation device (K ₂ CO ₃)	2 * Whatman 41 cellulose filters impregnated with K ₂ CO ₃ /glycerol soln	Determined as SO ₄ ²⁻ by ion-exchange chromatography	2 µg/m ³ (1 month)

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	$\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$	Integrated	Passive	Air is absorbed into the liquid media	Badge type - liquid media ($\text{NaHCO}_3 + \text{Na}_2\text{CO}_3$) is contained in a well of a sampler	Trapped SO_2 is converted by H_2O_2 to SO_4^{2-} , which is analyzed by IC-conductivity detector	N/A
	TEA, IC	Integrated	Passive	Diffusion onto a TEA-coated filter	A badge type (25 mm * 10 mm), Whatman 1 Chr filter paper (or two SS screens impregnated with TEA)	Absorbed SO_2 is converted by H_2O_2 to SO_4^{2-} , which is analyzed by IC	$0.7 \mu\text{g}/\text{m}^3$ (1 month), $21 \mu\text{g}/\text{m}^3$ (24 hr) -
	Low dose diffusive sampler (NaOH , IC)	Integrated	Passive	Diffusion onto a filter coated with NaOH	A badge containing a NaOH -impregnated Teflon membrane filter	Extracted SO_4^{2-} is measured by IC	$0.2 \mu\text{g}/\text{m}^3$ (1 month)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
PM ₁₀ / PM _{2.5}	Gravimetric methods - exchangeable filters	Integrated	Active	An air pump draws ambient air at a constant flow rate into an inlet	particulate matter is separated into size fractions and then collected on a filter	Net mass gain is divided by the total volume of air filtered -- > PM conc. In $\mu\text{g}/\text{m}^3$	
	Beta Attenuator Methods	Continuous	Active	Air is continuously drawn and particles are deposited on a filter tape	An air pump, a filter tape	Beta particles are attenuated when they pass through particulate deposits, which is a measure of the mass on the filter	$\sim 2 \mu\text{g}/\text{m}^3$ (1 hr) -
	Tapered Element Oscillating Microbalance (TEOM) Methods	Continuous	Active	Air is drawn through a tapered glass element with a filter attached	PM ₁₀ inlet, flow splitter, an air pump	The resonance frequency of the hollow glass element decreases as mass accumulates on the filter, directly measuring mass	$\sim 5 \mu\text{g}/\text{m}^3$ (5 min) -
	Real-Time Total Ambient Mass Sampler (RAMS)	Continuous	Active	Air is drawn through the system	Three TEA-coated annular denuders, two Nafion dryer, a BOSS carbon denuder	Measure mass concentration (including volatilized species) using a combination of TEOM principles with diffusion technology	$\sim 5 \mu\text{g}/\text{m}^3$ (1 hr) -
	Continuous Ambient Mass Monitor System (CAMMS)	Continuous	Active	Air is drawn through the filter	An air pump, a filter tape	A highly sensitive pressure transducer measures the differential pressure between measurement path and reference path	$\sim 2 \mu\text{g}/\text{m}^3$ (1 hr) -
	Piezoelectric Microbalance	Continuous	Active	Particles are deposited by inertial impaction or electrostatic precipitation on the surface of a piezoelectric quartz crystal disk	The natural resonant frequency of the crystal decreases as particle mass accumulates		$10 \mu\text{g}/\text{m}^3$ (1 min) -
	Personal Microenvironmental Aerosol Speciation Sampler (PMASS)	Integrated	Active	Air passes through a sampler using a personal pump	Cyclone inlet, Denuder, Filter holder	Net mass gain is divided by the total volume of air filtered -- > PM conc. In $\mu\text{g}/\text{m}^3$	

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Method Type	Type of Measurement	Sampler Tyoe	Collection Method	Sampling Device	Analytical Method	Range of Quantification (or detection)
	ChemPass Personal Sampling System	Integrated	Active	Air passes through a sampler using a personal pump	ChemPass Multi (or Single)-Component Sampling System (up to 4 filters + NO ₂ , SO ₂ and O ₃)	Net mass gain is divided by the total volume of air filtered -- > PM conc. In µg/m ³ ; Chemical speciation	
	Triplex CycloneSCC1.062 Triplex Cyclone	Integrated	Active	Air passes through a sampler using a personal pump	A sampling pump, cyclone	Net mass gain is divided by the total volume of air filtered -- > PM conc. In µg/m ³	
	GK2.05 (KTL)/GK2.05 SH (KTL) Cyclone	Integrated	Active	Air passes through a sampler using a personal pump	A sampling pump, cyclone	Net mass gain is divided by the total volume of air filtered -- > PM conc. In µg/m ³	
	Personal Microenvironmental Monitor (PEM)	Integrated	Active	Air passes through a sampler using a personal pump	An air pump, a monitor	Net mass gain is divided by the total volume of air filtered -- > PM conc. In µg/m ³	
	URG's Personal Sampler for Particulates/Pesticides	Integrated	Active	Air passes through a sampler using a personal pump	A sampling pump, a size-selective impactor inlet and filter pack, (PUF cartridge)	Net mass gain is divided by the total volume of air filtered -- > PM conc. In µg/m ³	

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Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Location of Sample	Importance of Route of Exposure	Importance of Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
Carbon monoxide (CO)	Indoor/ outdoor				Manufacturer's websites (e.g., http://www.monsol.com/Monitoring%20Solutions%2048C.pdf)			Automated Reference Method
	Personal				http://www.bis.fm/bis/products/Drager_Pac_III.asp			
	Outdoor				Watson, 1995. J. Air Waste Manag. Assoc. 45, 29-35.			
	Personal				http://www.msanet.com/day/17.html			
	Personal/indoor/ outdoor				Lee et al., 1992. Environ. Sci. Technol. 26, 697-702.			
	Personal (workplace)/ indoor/ outdoor				McConnaughey et al., 1985. Am. Ind. Hyg. Assoc. J. 46, 357-362; Valerio et al., 1997. Atmos. Environ. 31, 2871-2876.			
Nitrogen dioxide (NO ₂)	Personal				http://www.bis.fm/bis/products/Drager_Pac_III.asp			
	Indoor/ outdoor				http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml ; http://www.primeindia.com/manav/mangt20.html			Manual Equivalent Method
	Indoor/ outdoor				http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml ; http://www.primeindia.com/manav/mangt20.html			Manual Equivalent Method
	Outdoor				http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml (Fontijn te al., 1970. Anal. Chem. 42, 575-579).			Automated Reference Method
	Outdoor				http://www.opsis.se ; http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml			Automated Equivalent Method
	Indoor/ outdoor				http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml			Manual Equivalent Method

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Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Location of Sample	Importance of Route of Exposure	Importance of Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	Indoor (workplace)				Nitrogen dioxide in workplace atmosphere (ion chromatography) - OSHA, 1987 (Revised 1991)			
	Personal/Indoor/outdoor/workplace				Palmer et al., 1976. Am. Ind. Hyg. Assoc. 37, 570-577; Heal et al., 1999. Environ. Int'l 25, 3-8.		Protective cover recommended for outdoor sampling	
					NIOSH Manual of Analytical Methods, Nitrogen Dioxide (Diffusive sampler) - 6700; Hansen et al., 2001. J. Environ. Monit. 3, 139-145.		Short-term to a month; collection efficiency is temperature dependent (<-8°C)	
	Outdoor				Fern and Rodhe, 1997. J. Atmos. Chem. 27, 17-29.			
	Indoor/outdoor/personal				Mulik et al., 1989. Anal. Chem. 61, 187-189.			
	Outdoor/(indoor)				Tang et al., 1999. Field Anal. Chem. Technol. 3, 338-345.		Rain shelter (all seasons), can be used for low temp. and high humidity	
	(Indoor)/outdoor				Krochmal and Kalina, 1997. Atmos. Environ. 31, 3473-3479.		1 day - months, also used for NO ₂ measurement	
	(Indoor)/outdoor				Yamada et al., 1999. ES&T 33, 4141-4145.			
Ozone (O ₃)	Outdoor				www.epa.gov/ttn/amtic/criteria.html			Automated Reference Method
	Outdoor				www.epa.gov/ttn/amtic/criteria.html			Automated Equivalent Method
	Ambient (outdoor)				EPA-600/4-79-057 (1979); EPA-600/4-79-056 (1979); WMO GAW No. 97			Automated Equivalent Method
	Outdoor				http://www.opsis.se ; http://narsto.esd.ornl.gov/Compendium/methods/no2.shtml			Automated Equivalent Method
	Personal				http://www.epa.gov/ttn/amtic/ord/00212.txt			
	Personal				http://www.osha-slc.gov/dts/sltc/methods/inorganic/id214/id214.html			

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Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Location of Sample	Importance of Route of Exposure	Importance of Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	Outdoor				Hauser and Bradley, 1966. Anal. Chem. 38, 1529-1532.	Cannot be used below ~16°C	0.5 L/min, 0.5 to 2 hours	
	Outdoor				Moon and Hangartner, 1990. J. Air Waste Manag. Assoc. 40, 357-358.		1 week	
	Outdoor				Cox and Malcolm, 1999. Water Air Soil Pollution 116, 339-344.		2-3 weeks for sampling	
	Outdoor				Grosjean and Hisham, 1992. J. Air Waste Manag. 42, 169-173	NO ₂ and PAN would be potentials interferents	3-56 days	
					Grosjean et al., 1995. Environ. Pollution 88, 267-273		4-15 days	
					Bytnerowics et al., 1993. Environ. Pollution 80, 301-305.			
	Personal, outdoor				Koutrakis et al., 1993. Anal. Chem. 65, 209-214.		No change in collection rate due to temperature variation	
	Personal, outdoor				Brauer and Brook, 1995. J. Air Waste Manag. Assoc. 45, 529-533.			
	Outdoor				Tang and Lau, 2000. Environ. Monitoring and Assess. 65, 129-137.		High accuracy (1%<RE<14%)	
	Outdoor				Kano and Yanagisawa, 1992. Environ. Sci. Technol. 26, 744-749.	Interferences from NO ₂		
	Outdoor (forest or agricultural areas)				Serrano et al., 1993. Atmos. Environ. 27A, 431-442.			
	Personal				http://www.bis.fm/bis/products/Drager_Pac_III.asp			
Sulfur dioxide (SO ₂)	Indoor, outdoor				40 CFR part 50, Appendix A		(30 min - 24 hr)	Manual Reference Method
	Ambient				USEPA, List of Designated Reference and Equivalent Methods, Oct. 9, 2003 (www.epa.gov/ttn/amt/criteria.html)			Automated Equivalent Method
	Outdoor				www.epa.gov/ttn/amt/criteria.html			Automated Equivalent Method

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Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Location of Sample	Importance of Route of Exposure	Importance of Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	Outdoor				Ferm and Svanberg, 1998. Atmos. Environ. 32, 1377-1381.			
	Outdoor				Ferm and Svanberg, 1998. Atmos. Environ. 32, 1377-1381.			
	Outdoor				Huey, 1968. J. Air Pollut. Control Assoc. 18, 610-611.	Analysis is time-consuming	30 days	
	Outdoor				Reisner and West, 1973. ES&T 7, 526-532,	No significant errors from interferents (H ₂ S, NO ₂ , O ₃)	6 hr - 7 days	
	Outdoor				Orr et al., 1987. Atmos. Environ. 21, 1473-1475.			
	Indoor (workplace)				Hallberg and Rudling, 1998. Ann. Occup. Hyg. 33, 61-68.			
	Outdoor				Krochmal and Kalina, 1997. Atmos. Environ. 31, 3473-3479.		1 day - months, also used for NO ₂ measurement	
	Outdoor				Carmichael et al., 1995. Water Air Soil Pollution 85, 2289-2294.		1 month	
					Ferm and Svanberg, 1998. Atmos. Environ. 32, 1377-1381.			
					Ayers et al., 1998. Atmos. Environ. 32, 3578-3592.			
PM ₁₀ /PM _{2.5}	Ambient				http://narsto.ornl.gov/Compendium.methods/pm.shtml		PM ₁₀ /PM _{2.5}	Manual Reference Method
	Ambient				McMurry, 2000. Atmos. Environ. 34, 1959-1999.		PM ₁₀ /PM _{2.5}	Automated Equivalent Method
	Ambient				McMurry, 2000. Atmos. Environ. 34, 1959-1999.		PM ₁₀ /PM _{2.5}	Automated Equivalent Method
	Ambient				McMurry, 2000. Atmos. Environ. 34, 1959-1999.		PM ₁₀ /PM _{2.5}	
	Ambient				McMurry, 2000. Atmos. Environ. 34, 1959-1999.		PM ₁₀ /PM _{2.5}	
	Ambient				McMurry, 2000. Atmos. Environ. 34, 1959-1999.		PM ₁₀ /PM _{2.10}	
	Personal/Micro environment				MSP Corporation		4.0 L/min, 37 mm, 300 g, two channels, PM _{2.5}	
	Personal				Rupprecht & Patashnick Co, Inc.		0.8, 1.8 or 4.0 L/min, 37 mm, PM ₁₀ /PM _{2.5}	

(continued)

Table A-1. Summary of Collection Methods For Gaseous Pollutants and Particulates in Air (continued)

Contaminant	Location of Sample	Importance of Route of Exposure	Importance of Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	Personal/Ambient				BGI, Inc.		37 mm, 1.05 to 3.5 L/min, PM _{2.5}	
	Personal/Ambient				BGI, Inc.		37 mm, 4.0 L/min, PM _{2.5}	
	Personal/Ambient (Indoor)				SKC, Inc.		37 mm, 2, 4 or 10 L/min, PM ₁₀ /PM _{2.5}	
	Personal/(Ambient)				URG		25 mm, 4 L/min, PM ₁₀ /PM _{2.5}	

Table A-2. Summary of Collection Methods for Metals in Air

Entry	Contaminant	Size Cut	Sampler type	Measurement type	Sampler Type	Collection media	Sampling Device and sampling duration	Analytical Method
1	Total Metals	TSP	Filter based sampler	Integrated	Active	Quartz filter	High-Vol sampler at 68 m ³ /h for 24 h	acid digestion for metals analysis with ICP/AES and/or ICP/MS
2	Total Metals	TSP	Filter based sampler	Integrated	Active	same as above	same as above	X-ray absorption fine structure (XAFS) spec
3	Total Metals	TSP	Filter based sampler	Integrated	Active	Whatman EPM 2000 borosilicate glass microfiber filter	General Metals Works BM 2200X portable high-vol sampler, 631-3481 m ³ of air over 48 hrs	Atomic Absorption Spec (AAS)
4	Total Metals	TSP	Filter based sampler	Integrated	Active	Whatman-41 filter (12.5 cm diameter)	Gamma Irradiation Center of AEOI sampler @ 5 m ³ /h	Instrumental neutron activation analysis (INAA)
5	Total Metals	TSP	Filter based sampler	Integrated	Active	25-mm filters: Glass fiber, 1.0 um, PVC, 5.0 um, or Teflon w/ PMP support, 3.0 um	SKC abrasive blasting sampler for heavy metals @ 2-10 lpm (4 lpm recomm) for 8 h	ICP used for 25 metals, visual absorption spe (VAS) used for hexavalent Cr
6	Total Metals	TSP	Biomonitor	Integrated	Passive	plants	T. capillaris	AAS
7	Total Metals	TSP	Filter based sampler	Integrated	Active	8"x10" quartz filter	High-vol sampler @ 40-60 cfm for 24 h	ICP/MS
8	Hg	TSP	Filter based sampler	Integrated	Active	6-mm quartz fiber filter disc supported by Ni-screen	AESminiSamplR At 3.5-5.5 lpm	Hg thermally desorbed at 900 C onto a gold trap which is desorbed at 550 C and detected on atomic fluorescence spec.
9	Pb	PM ₁₀	Immunoassay	Integrated	Active	fiberglass filter	N/A	Filter extracted nitric acid and HCl, pipeting into assay reagents, and polarization was measured by FPIA
10	As, Pb, Cd, Cr	PM ₁₀	Filter based sampler	Integrated	Active	Teflon	?	As by hydride generation atomic fluorescence (HGAF), Pb, Cd, and Cr by GFAAS
11	Pb, As, Cd, Cr, Ni	PM ₁₀	Filter based sampler	Integrated	Active	Teflon	Air pumped at 4 lpm for 72 h (O'Rourke et al. 1999) or high-vol sampler (Libowitz et al. 1995)	XRF, ICP-AES (or HG-AAS).
12	Total Metals, esp. Pb	PM _c and PM _{2.5}	Filter based sampler	Integrated	Active	?	"Gent"-type stacked filter sampler @ 16 lpm	PIXE and SEM and ED X-ray microanalyzer (EDX) for individual particle
13	Total metals	PM _{2.5}	Filter based sampler	Integrated	Active	25-MM Teflon filter	IMPROVE, cyclone, @ 22.7 lpm for 24 h	XRF (enhanced sensitivity), PESA

(continued)

Table A-2. Summary of Collection Methods for Metals in Air (continued)

Entry	Contaminant	Size Cut	Sampler type	Measurement type	Sampler Type	Collection media	Sampling Device and sampling duration	Analytical Method
14	Total metals	PM _{2.5}	Filter based sampler	Integrated	Active	46.2-mm Teflon filter	STN, cyclone or Wins impactor (16.7 lpm for Teflon filter pack) for 24 h	XRF (enhanced sensitivity), PESA
15	Total metals	PM _{2.5} , PM ₁ , PM ₁₀ , or TSP	Filter based sampler	Integrated	Active	Partisol filter	Partisol air sampler 2000 @ 16.7 l/min for 24 h	ICP or AA
16	Total metals	PM _{2.5} , PM ₁ , PM ₁₀ , or TSP	Filter based sampler	Integrated	Active	Series 1400a filters	TEOM Series 1400a monitor @ 3 lpm (24 h to 14 days)	ICP or AA
17	Mn, Al, Ca, Mg	PM _{2.5} and PM ₁₀	Filter based sampler	Integrated	Active	N/A	MSP sampler, 3 min on and 1 min off over 3 days @ 2 lpm	Neutron activation
18	Mn, Al, Ca, Mg	PM _{2.5} and PM ₁₀	Filter based sampler	Integrated	Active	N/A	Graseby-Anderson dichotomous sampler with 4 D-cell batteries, 2.4 m ³ air collected over 24 h for coarse and 21.6 m ³ for fine PM.	Neutron activation

(continued)

Table A-2. Summary of Collection Methods for Metals in Air (continued)

Entry	Range of Quantification or detection	Sampling Location	Importance of inhalation exposure	Importance to outdome	Lifestage	Reference	Limitations	Comments
1	N/A, rough recoveries: 74-116%	Outdoor				Pineiro-Iglesias, M. et al. A new method for the simultaneous determination of PAH and metals in samples of atmospheric particulate matter. Atmos. Environ. 37 (2003) 4171-4175		PAH and metals can be analyzed simultaneously
2	N/A	Outdoor				Pineiro-Iglesias et al. 2003. Huggins , FE, et al. Speciation of elements in NIST particulate matter SRMs 1648 and 1650. J. Hazard. Mater. 2000, 74, 1-23.		XAFS is an element-specific structural analysis, useful for trace element speciation and forms of occurrence in chemically and structurally complex materials.
3	Detection limits (ng/ml). Cd:12, Zn:20, Cu:22, Mn:41, Cr:55, Ni:65, Fe:68, Pb:81.	Outdoor				Bilos , C. et al. Sources, distribution and variability of airborne trace metals in La Plata City area, Argentina. Environ. Pollution 111 (2001) 149-158. Kim , K.-H. Environ. International 29(2003) 901-906. Pilger and Broder. Determination of metals on airborne particulates by AAS. IARC Schi Publ. 1993 (109) 328-41.		
4	N/A	Outdoor				Hadad, K. et al. Impact of different pollutant sources on Shiraz air pollution using SPM elemental analysis. Environ. International 29 (2003) 39-43.	INAA is useful for Mn, V, Fe, Zn, Cr, Br, Ca, and Sc (Pb is impractical). AAS was used for Cu, Al, Mn, and Pb.	AAS was used to complement the INAA method. Whatman-41 filter produces low background metals and does not interfere INAA.
5	N/A	Outdoor, Indoor, Personal				Aizenberg et al. Metal exposures among abrasive blasting workers at 4 U.S. Air Force facilities. Appl. Occ. Environ. Hyg. 2000. 15 (2000) 766-772.	VAS can not detect Cr(II) and (III) due to chemical interference from iron and some other metals.	This sampler withstands mechanical stress, prevents collecting very large PM, and prevents filter overloading and particle rebounding.

(continued)

Table A-2. Summary of Collection Methods for Metals in Air (continued)

Entry	Range of Quantification or detection	Sampling Location	Importance of inhalation exposure	Importance to outdome	Lifestage	Reference	Limitations	Comments
6	N/A	Outdoor	low			Pignata et al. Atmospheric quality and distribution of heavy metals in Argentina employing Tillandsia capillaris as a biomonitor. Environ. Pollut. 2002, 120(1): 59-68	These plants are not prevalent in U.S.	Used for detecting Co, Cu, Fe, Ni, Mn, Pb, and Zn.
7	N/A	Outdoor				Leston , A.R. Air Toxics methodology issues, EPA/NESCAUM workshop, Oct 8-9, 2003, Las Vegas, NV US EPA , IO Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, EPA/625/R-96/01a, July 1999	digestion problem (poor recovery)? Bias in mass determination?	This methodology was used by the Air Toxics "Pilot Cities" including Seattle
8	in pg/m ³	Outdoor, Indoor, Personal				of the AESmniSamplR technique for sampling and analysis of total particulate mercury in the atmosphere. The science of the Total Environ. 304 (2003) 115-125.		Sample analysis time is less than 10 min. This method was designed for ecological monitoring.
9	N/A (probably low ppm)	analytical alternative				Johnson et al. Lead analysis by anti-chelate fluorescence polarization immunoassay. ES&T, 2002, 36, 1042-1057.	Some bias	R ² between this method and AAS is between 0.96 and 0.93.
10	MDL: As: <1 ng/m ³ , Pb: 10 ng/m ³	Outdoor, Indoor, Personal	High	High		Pellizzari et al. An assess of the data quality for NHEXAS-part I: exposure to metals and VOC in Region 5. JEAE (2001) 11, 120-154.		

(continued)

Table A-2. Summary of Collection Methods for Metals in Air (continued)

Entry	Range of Quantification or detection	Sampling Location	Importance of inhalation exposure	Importance to outdome	Lifestage	Reference	Limitations	Comments
11	MDL (ng/m ³): Pb: 661-35,886 As: 1.8-14.3, Cd: 37-444, Cr: 59-3179, Ni: 85-1778	Outdoor, Indoor, Personal				Lebowitz et al. Population-based exposure measurements in Arizona: a phase I field study in support of the NHEXAS. JEAEE (1995) 5, 297-325. O'Rourke et al. Evaluations of primary results from NHEXAS Arizona: distributions and preliminary exposures. JEAEE (1999) 9, 435-445.		
12	N/A	Outdoor				Biswas et al. Impact of unleaded gasoline introduction on the concentration of lead in the air of Dhaka, Bangladesh. JAWMA (2003) 53:1355-1362.		
13	?	Outdoor				Solomon et al. Air Toxics methodology issues, EPA/NESCAUM workshop, Oct 8-9, 2003, Las Vegas, NV		
14	?	Outdoor				Solomon et al. Air Toxics methodology issues, EPA/NESCAUM workshop, Oct 8-9, 2003, Las Vegas, NV	LOD is not sufficiently sensitive	
15	ICP (ng/m ³): Pb: 104.1 ng/m ³ Cd: 10.4 Ni: 62.5 As: 20.8 AA (ng/m ³): Pb: 7.5, Cd: 0.8, Ni: 20.8, As: 10.4	Outdoor				Rupprecht & Patashnick Co., Inc. http://www.rpco.com/products/ambprod/amb2000/metals.htm (viewed on 1/8/2004)		
16	Assuming 24 h. AA: Pb: 41.7, Cd: 4.6, Ni: 115.7, As: 57.9. ICP: Pb: 578.7, Cd: 57.9, Ni: 347.2, As: 115.7	Outdoor				Rupprecht & Patashnick Co., Inc. http://rpco.com/products/ambprod/amb1400/metals.htm (viewed on 1/8/2004)		

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Table A-2. Summary of Collection Methods for Metals in Air (continued)

Entry	Range of Quantification or detection	Sampling Location	Importance of inhalation exposure	Importance to outdome	Lifestage	Reference	Limitations	Comments
17	Detection limits (ng/m ³): Al: 27, Ca: 96, Mg: 93, Mn: 0.170	Outdoor, Indoor, Personal	High	High		Pellizzari et al. Particulate matter and manganese exposures in Indianapolis, Indiana. JEAAE (2001) 11, 423-440.		
18	For V=6.48 m ³ , Instrumental DL (ng/m ³): Mn: 0.73-0.84. DL based on blanks. Mn in PM ₁₀ : 5.5. Mn in PM _{2.5} : 1.83	Outdoor	High	High		Pellizzari et al. Particulate matter and manganese exposures in Toronto, Canada. Atmos. Environ. 33 (1999) 721-734.		

Table A-3. Summary of Collection Methods for Volatile Organics in Air

Contaminant	Method Type	Type of Measure-ment	Sample Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification	Location of Sample
Volatile Organic Compounds	Passivated canister sampling (EPA ref. methods TO-12, TO-14 and TO-15)	Integrated	Active	Whole air. Drawn into a stainless steel canister with passivated walls; evacuated or pressurized. Canisters available in volumes from 400ml (MiniVac) to +6 liters	Passivated stainless steel canister with flow controls; pressurized or evacuated.	Direct injection. Analyses by GC with FID/ECD or GC/MS after direct cryogenic trapping (non-polar compounds) or on a multi-sorbent/second trap (polar and non-polar compounds).	0.01ppb to < 1 ppm level (with injection dilution) MDL varies by compound	Indoor/ outdoor/ personal (with MiniVac)
	VOCs condense as they flow through a trap cooled to $\approx -50^{\circ}\text{C}$.	Integrated	Active	Whole air is drawn at a constant rate through a cryogenically cooled trap to condense VOCs. EPA TO-3.	Metal trap immersed in liquid oxygen or argon at -50°C	Thermal desorption followed by GC/FID/ECD	0.1-200ppb	indoor/ outdoor
	Granular sorbent material in a tube or cartridge adsorbs VOCs.	Integrated or intermittent	Active	Sorbent. Air is drawn through a single sorbent bed. Effectiveness of collection is sorbent and VOC-class specific. Sorbents include: 1) Polymers: TENAX GC [EPA TO-1] or TA; XAD; 2) granular carbons: activated charcoal; various types of graphitized carbons; carbon molecular sieve (EPA TO-2)	Cartridge or tube filled with single sorbent, pump and flow controls	Thermal desorption followed by GC/FID/ECD or GC/MS	MDL varies by compound and is strongly dependent of sorbent background.	Indoor/ outdoor/ personal
	Granular sorbent materials in a tube or cartridge adsorb VOCs.	Integrated or intermittent	Active	Air is drawn at a constant rate through a bed of multiple sorbents separated by foam plugs. Utilizes the optimal sorbent material for each VOC class. Analysis by GC/MS following thermal desorption.	Cartridge or tube filled with separate beds of different sorbents	Thermal desorption followed by GC/MS (EPA TO-17) or GC/FID/ECD	MDL varies by compound and is strongly dependent of sorbent background.	Indoor/ outdoor/ personal
	VOCs diffuse as a function of concentration gradient and are adsorbed on a sorbent.	Integrated	Passive	Compounds diffuse passively onto a sorbent bed or sorbent pad	Diffusion badge or diffusion tube.	Thermally desorbed or solvent extracted depending on the type of sorbent: graphitic carbons and polymers are thermally desorbed; activated charcoal is solvent-extracted. Thermal desorption results in lower detection values because the sample is not diluted prior to analysis.	ppb to ppm levels	Personal/indoor/ outdoor

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Table A-3. Summary of Collection Methods for Volatile Organics in Air (continued)

Contaminant	Method Type	Type of Measure-ment	Sample Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification	Location of Sample
Carbonyl compounds	Compounds with a carbonyl moiety such as aldehydes and ketones react with DNPH in an impinger solution to produce compound-specific derivatives amenable to separations by HPLC and detection by UV/VIS.	Integrated	Active	Air drawn through an impinger containing a solution of DNPH	Impinger with DNPH solution	Analysis of solution by HPLC with UV/VIS	1-50ppbv	Indoor/ outdoor
	Compounds such as aldehydes and ketones react with DNPH coated on a polymeric support (typically C18) contained within a tube or cartridge.	Integrated	Active	Air passes through a tube or cartridge filled with a polymeric support coated with DNPH.	Cartridges or tubes filled with DNPH-coated C18, KI trap (to remove Ozone interferences), pumps and flow controls.	Extraction with acetonitrile followed by HPLC with UV/VIS analysis	0.5 to 100 ppbv	Indoor/ outdoor/ personal
	Compounds with a carbonyl moiety such as aldehydes and ketones react with DNPH coated on a fiber or filter support glass support	Integrated	Passive	Carbonyl compounds diffuse onto the coated support and react to produce DNPH derivatives	Commercially available badge (e.g. GMD badge)	Extraction with acetonitrile followed by HPLC with UV/VIS analysis	0.05 - 100 ppb	Indoor/ outdoor/ personal
	Compounds with a carbonyl moiety such as aldehydes and ketones react with DNSH coated on a C18 support	Integrated	Passive	Carbonyl compounds diffuse onto a DNSH-coated support placed inside a cartridge. Compound-specific derivatives of DNSH-carbonyls fluoresce. Fluorescence is a more sensitive method of detection than UV/VIS	Cartridge not commercially available but can be easily prepared from commercially available materials.	Extraction with acetonitrile and analysis by HPLC with fluorescence detector.	0.01 - 100 ppb	Indoor/ outdoor/ personal
Nicotine	Airborne nicotine diffuses to a filter coated with sodium bisulfate	Integrated	Passive	Nicotine diffuses to a fiber glass or quartz filter coated in sodium bisulfate that is held in a cassette.	Cartridge not commercially available but can be easily prepared from commercially available materials.	HPLC with UV/VIS detection.	0.01 - 100 ppb	Indoor

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Table A-3. Summary of Collection Methods for Volatile Organics in Air (continued)

Contaminant	Method Type	Type of Measure-ment	Sample Type	Collection Method	Sampling Device	Analytical Method	Range of Quantification	Location of Sample
PAHs	Air is drawn through a filter followed by a sorbent bed to collect particle-bound and gas phase PAHs.	Integrated	Active	Collection of particle-bound fraction on a prefired glass fiber or teflon filter with a PUFF or XAD-2 sorbent cartridge placed downstream to collect the gas fraction.	Filters and cartridges are commercially available and can be fitted to either hi-vol or microenvironmental samplers. Allows for size-selected sampling	Extraction by sonication (filter) and soxlet extraction (sorbent); analysis by GC/MS	0.5 - 500 ug/m ³	Indoor/ outdoor

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Table A-3. Summary of Collection Methods for Volatile Organics in Air (continued)

Contaminant	Importance of Route of Exposure	Importance to Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
Volatile Organic Compounds	High	Medium (depending on compound class)	≥ 18 (for personal monitoring); all ages for outdoor monitoring; all ages for indoor monitoring with precautions	http://www.epa.gov/ttn/amtic/ord/00313.wpd ; http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-15r.pdf ; http://www.epa.gov/ttn/amtic/ord/00322.wpd ; http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-14ar.pdf ; http://www.epa.gov/ttn/amtic/files/ambient/airtox/tocomp99.pdf	EPA reference method. Requires careful clean up to avoid contamination. Questionable for some polar compounds. High participant burden when used as personal sampler. Not suitable for young children.	Canister methods have been extensively evaluated by EPA and the performance and QA/QC parameters are relatively well established. Direct injection with or without cryogenic trapping avoids dilution of sample. High cost.	Automated Reference Method
	High	Medium (depending on compound class)	Not suitable for personal monitoring. Questionable for indoor use.	http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-3.pdf	Avoids limitations of sorbent sampling. Very cumbersome for sampling because it requires supervision.	There is experience for outdoor sampling. EPA SOPs and QA/QC are available. High cost.	Not automated. Equivalent method.
	High	Medium (depending on compound class)	≥ 12 (for personal monitoring); all ages for outdoor monitoring; all ages for indoor monitoring with precautions. Less cumbersome than canister sampling.	http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-1.pdf ; http://www.epa.gov/ttn/amtic/files/ambient/airtox/tocomp99.pdf	Different sorbents are appropriate for different classes of compounds; thermal desorption avoids sample dilution; sorbent can be reused following thermal cleaning but background of certain compounds could increase because of decomposition in the case of polymeric sorbents; certain sorbents are specially affected by high humidity; breakthrough can be a problem. High participant burden because of the need for personal sampling pump.	There is extensive experience with the use of some sorbents for indoor, outdoor and personal monitoring. EPA SOPs and QA/QC are available for equivalent methods.	Equivalent Method

(continued)

Table A-3. Summary of Collection Methods for Volatile Organics in Air (continued)

Contaminant	Importance of Route of Exposure	Importance to Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	High	Medium (depending on compound class)	≥ 12 (for personal monitoring); all ages for outdoor monitoring; all ages for indoor monitoring with precautions. Less cumbersome than canister sampling.	http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-17r.pdf ; http://www.epa.gov/ttn/amtic/files/ambient/airtox/tocomp99.pdf	A combination of sorbents allows for simultaneous sampling of more than one class of compound. Multiple sorbent tubes can be purchased commercially or made for particular applications.	There is extensive experience with the use of some sorbents for indoor, outdoor and personal monitoring. EPA SOPs and QA/QC are available (EPA TO-17).	Equivalent Method
	High	Medium (depending on compound class)	≥ 6 (for personal monitoring); all ages for outdoor monitoring; all ages for indoor monitoring with precautions. Far more acceptable to individuals than active sampling because of the low participant burden. Lower in cost than active methods.	Chung et al., 1999 a, b.	Sampling rates comparably low compared to active sampling. Sorbent limitations similar to active sampling with sorbents. Compound class depends on specific sorbent. Sorbents that require solvent extraction result in dilution of the sample.	Several types of passive monitors are commercially available. Some models use a sorbent bed that can be replaced with other sorbents.	Some passive samplers have been used extensively in exposure studies in the US and Europe.
Carbonyl compounds	High	Medium (under investigation)	Because a solution is used, the method is not appropriate for personal monitoring in the general population. Applicable to all ages for outdoor monitoring and with appropriate precautions for indoor monitoring. Not suitable for acrolein. Potential for evaporation of the solution during sampling.	http://www.epa.gov/ttn/amtic/files/ambient/airtox/tocomp99.pdf	Significant experience because of the well known reactions. Interferences with oxidizing compounds in air may affect results unless a trap is used to remove compounds such as ozone from the air stream.	Solution is prepared in the laboratory	Not automated. Equivalent method (EPA TO-5)
	High	Medium (under investigation)	Avoids the use of a solution to capture carbonyl compounds, so it is more appropriate for personal monitoring. Same limitations with respect to acrolein. Active sampler requires a pump, so suitable for ≥ 12.	http://www.epa.gov/ttn/amtic/files/ambient/airtox/tocomp99.pdf	Significant experience because of the well known reactions. Interferences with oxidizing compounds in air may affect results unless a KI trap is used to remove compounds such as ozone from the air stream.	Cartridges are commercially available but they can be easily prepared also.	Manual. Equivalent Method (EPA TO-11A)

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Table A-3. Summary of Collection Methods for Volatile Organics in Air (continued)

Contaminant	Importance of Route of Exposure	Importance to Outcome	Lifestage	References	Limitations	Comments	FRM or FEM?
	High	Medium (under investigation)	Suitable for outdoor, indoor and personal monitoring ≥ 6 years of age.	Morandi et al, 1998; Others.	Limitations for acrolein sampling. High background levels are a problem.	Used extensively for outdoor/indoor/ personal monitoring in European studies and in some US studies.	
	High	Medium (under investigation)	Suitable for outdoor, indoor and personal monitoring ≥ 6 years of age. Detects acrolein.	Zhang et al, 2000	This is still a research tool and not fully evaluated	Used in indoor/ outdoor/ personal monitoring studies in the US. It is better that the DNPH methods for acrolein.	
Nicotine	High	High (ETS indicator)	Suitable for indoor monitoring. Requires multiple day exposure.	Hammond and Leaderer, 1987 et al,	Research tool.	Used in several studies of impact from ETS in indoor environments.	
PAHs	High	Medium (under investigation)	Suitable for indoor and outdoor monitoring when using microenvironmental samplers. There	Turpin et al, 2002	The lower molecular weight PAHs may not be collected efficiently. Extraction solvent volumes need to be adjusted depending on the volume of the sample.	Method can be used for hi volume sampling in ambient air (EPA TO-13A)	FRM (EPA TO-13A)